Tree Risk Management and Hazard Assessment: A General Review

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Management of the urban forest includes maintenance, protection and prevention of problems. Management denotes resource expertise at the organism level, and familiarity and working knowledge of our social systems. In addition, cost-effectiveness over the long-run binds objectives, symptom recognition, treatments, and expected results into a core of resource management decision making that demands up-to-date and conscientious managers.

The manager must know the tools and expected results of urban forest maintenance. The manager must also understand how to technically assess the condition of the resource. Hazard assessments are critical components of urban forest inventories. They should be systematically completed by trained professionals. There are several means and methods for assessing hazard conditions and appraising potential risks in the urban forest.

Community foresters are risk managers. Most large corporations and public institutions have people assigned to risk management with the stated goal of reducing liability exposure. The community forest has many risks associated with its functions and the values it produces. At the very least, trees are tall, large, and dense structures that can lose parts or catastrophically fail. The assessment of tree 'associated risk requires specific training and familiarity of both the legal system and trees and their sites.

Appreciating Risk

One of the most glaring word uses in risk assessment is the word "hazard." The word hazard, for both lay-people and professionals denote that some threshold of risk has been surpassed. Hazard also conveys the immediacy of structural failure as determined by a tree professional. Within community forestry, it is critical that the word "hazard" be used only in association with situations where an actual hazard has been identified. The hazard concept demands a completed evaluation and assessment of risk which reaches a management threshold where the situation cannot be allowed to continue. Beware of the misuse or overuse of the word "hazard."

Every landscape and tree situation has risk involved. Nothing is risk free. All trees carry a given amount of risk. That level of risk under some management regimes would be hazardous while under other management objectives would be acceptable risk. Some situations allow more risk to be

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accepted and managed, while other situations would call for immediate removal and risk reduction. Because all trees have risk associated with them, discussion of the structural integrity of a tree should assess the level of risk present. It is the amount of risk present, the perceptions of the risk manager, and the willingness to accept or not accept a given level of risk that determines hazard. Any tree is not necessarily hazardous, but all carry some level of assessable risk that professionals can estimate.

Tree Values and Liabilities

One of the fundamental concepts in community forest management is that trees have value, provide benefits, and are desired by humans. People find great psychological, monetary, aesthetic, and utilitarian values in trees. The benefits of trees which people enjoy include aesthetic, recreation, psychological, shade, heat dissipation, blockage of glare, blockage of noise, production of white noise, reduction of pollutants, production of oxygen, reduction of erosion, wildlife habitat, increase property values, and increase economic stability. Many more values and functions could be added.

Trees have great benefits but also have great costs. Tree costs include capital infrastructure investments, foregone alternative investments, installation, maintenance, management, and removal. One of these costs is liability risk. Liabilities include ecological, biological, aesthetic, social, economic, and safety risks. You cannot eliminate liability risk from trees unless the entire above and below ground structure is removed from the site. With the trees removed, the site still does not remain risk free. A manager can reduce liability risks and keep them below the management objective threshold, in most cases. People want trees but they also need to be safe from threats to property and physical injury.

Part of management is being aware of the potential risks associated with trees, identifying risks, and then minimizing risks within the constraints of your management objectives. This process depends upon professional judgements and decisions (or lack of decisions). Every professional decision must be made for one or all the following reasons: asset protection, asset appreciation, minimization of liability risks (future), public safety (present), and/or to reach management objectives. Understanding the structure of trees, symptoms of impending structural failure, treatments available to minimize the chance of structural failure, and how trees finally fail are essential knowledge to a community forestry manager. Understanding the risks of structural failure is as important as any other component of a manager's job.

Definitions

There are three classes of trees in the landscape related to levels of risk. The first is a "hazard tree." The attributes of a hazard tree are it has a major structural fault that could lead to catastrophic loss and it has an identifiable target (people or property). The second class of tree is a "tree at risk" of catastrophic failure or with a significant target profile potentially leading to great injury and harm. A "tree at risk" has potential for becoming a hazard tree. The third class is all the rest of the trees present with known risk assessments, or as yet undetermined associated risks. The amount of acceptable risk is dependent upon the management objectives of the site and the owner's / manager's perceptions and expectations of tree performance.

Structural Faults

Because a hazard condition has two components (a major structural fault and a target), let us examine structural faults and tree defects. Structural defects are dependent upon fault length, width, and depth, tree species, tree vigor, and associated compounding structural problems. Hazard assessment is only about structure, not about aesthetics or biology. Structural defects can include large

vertical (longitudinal) cracks, large decayed areas, included bark zones, narrow crotches or forks, dead wood and branches, large cavities, large leans, major root damage, horizontal (tangential) cracks, poorly connected living branches, pest damaged or modified areas, and mis-proportioned crown / root ratio and stem strength for the given wind and gravity loading conditions. There are many unique forms of tree failures.

Specific Cases of Structural Faults

There are several structural failures that reap the much attention. One structural fault of interest is branch drop cause by longitudinal cracks. These cracks can form: along compartment lines of old pruning cuts or injuries; from structural failures along cell walls due to loading stress and strain (bending, tensioning, compression, and twist); and, from negative transpirational pressures. There are many other specific causes. Cracking leads to wound colonization by wood weakening organisms, decreases moisture content which facilitates more injury, and pest attacks which weaken the structural and defensive components of the branch or tree. The final result is the sometimes sudden loss of living branches.

Another structural failure for consideration is in the root plate or root pedestal area at the base of the stem. As trees sway in the wind and are loaded by wind and gravity, the basal roots and lower stem undergo alternating periods of compression and tension. Tree structure is two to three times weaker in compression than in tension. Where structural areas are loaded beyond their compressive limits, fault lines develop that will expand as more compressive load is added over time and will fail under compression or tension. For example, many trees damaged in storms show compressive failures which fail under tension. Root pulling and shearing across their cross-section are the result.

Root collar problems are receiving much more (well deserved) attention from a structural standpoint. Bark and cambial damage, especially if repeated over many years can lead to many types of structural problems in the very place in the tree where stress and strain is concentrated. Injury at the stem base and in the root collar area can be hidden by soil and landscape features. Root collar excavations are becoming more common as a part of risk assessments.

One structural component fault that is sometimes overlooked is girdling roots. Girdling roots are hard to diagnosis and can lead to strength losses. The effect of poor root geometry development can lead to significant risks of tree failure after 10-20 years. Generally, root structural problems of any kind are difficult to ascertain, requiring additional care in assessments.

Leaning trees have plagued people since the first lean-to was erected. The perceptions and expectations of nonprofessionals when observing a leaning tree is highly variable and govern the amount of risk accepted. Leaning trees could stand for millennium or fall tomorrow. Professional judgement about the structural integrity of leaning trees many times takes a backseat to manager / owner anxiety about impending failure. Trees with progressive leans are clear candidates for removal. Trees that have not changed stem positions relative to the ground and surrounding obstacles for decades probably carry little additional risks other than in specific directional targeting. It is difficult to defend having left a tree with a significant lean (15-20°) when it fails.

Professional Observations

The amount of damage that can be visible and still allow a tree to remain is a professional judgement. Several application rules have been developed. The new pruning standards suggests when 1/2 the circumference is damaged, the tree should be considered for removal. From a mechanical structure standpoint, this is not conservative enough. Once circumferential damage reaches 1/3 or more, removal should be considered. Err on the side of human safety.

Remember in examining trees to determine structural integrity not surface appearance. Blemishes that lay-people might consider significant should be examined for structural consequences, but discarded if found to be only a blemish. Find what is the most limiting structural component in the tree and then estimate the risks associated with its failure. Experience of the assessor is critical to risk management evaluations. Do not send inventory counters to make risk assessments without training, practice, and spot-checking performance.

Structural failures in trees can generally be summarized as 40% in branches, 30% in stems, and 30% in root crowns and roots. This roughly even distribution suggests several things to a tree professional. The first is that trees are structurally designed to not fail at any given point more than any other. Trees are well equipped to handle stress and strain in their environments. The second suggestion is that failure patterns need to be learned and expectations drawn for prudent management. Careful observation is needed of all parts of a tree to effectively summarize risk levels.

Target Risks

Now that structural concerns have been reviewed, let us review the second piece of a hazard tree assessment which is the presence of a target(s). Risk assessment targets are people and property. Anywhere people would walk, drive, stand, lay, run, recreate, etc. could be a target area. Sidewalks, streets, parking lots, ball fields, golf courses and parks are all prime target areas. Property targets most often damaged by trees are cars, fences, buildings, roofs, pavement, yards, and gardens. Personnel injury targets and property targets are usually interrelated. Minimize risk to all personal injury targets.

There are many types or classes of targets and some risk management systems try to prioritize management activities by target risk class. This type of target classification is dangerous in community forest risk assessment. Because of legal views of prudent and reasonable behavior by a manger, the only reasonable means of prioritizing by target are people vs. property. The more people, or the more valuable the property, the more target exposure.

Legal Responsibilities

The legal framework for working with tree risks and structural failure varies by location. A community forest manager should always seek professional legal advice when needed. The framework of negligence, injury, and legal tests for prudence and reasonableness are important for understanding the implications of risk. Here I will briefly review general legal components of hazards in a community forest.

For community forest managers, actions (and non-actions) will be judged for prudence, (which is the wisdom to look ahead and develop expectations about what can happen), and reasonableness, (which is the lack of negligence), A manager's decisions must meet both of these tests under risk management programs, with the major point of contention being negligence.

In a general sense, negligence is composed of four features that must all be true for negligence to be proved. These four features of negligence are: 1. You have a duty to exercise reasonable care; 2. You failed in that duty; 3. Failure in duty caused injury; and, 4. Injury caused real harm to people and/or property. The critical first step is determining your duty under the law.

Duty Concepts

Case law and common law has delineated a difference between duty principles in rural versus urban settings. Traditionally in rural settings, an owner / manager had a duty to correct or remove known hazards. Duty principles continue to evolve but generally suggest a greater level of duty in urban / suburban areas. In urban areas duty has included removal of known hazards and, in addition,

inspection for hazards. Inspection for hazards is a burden that must be met to prevent a failure in duty and charges of negligence. The heighten duty in urban/suburban areas carry over into areas where tree failures could impact roads and trails.

Failure in duty can be substantiated by expert testimony and/or by not following customary practice without clear and substantial reasons. This would suggest that failing to follow ANSI pruning standards would be a place of contention in determining negligence. Ignorance by the manager or inspector is challengeable. The action or lack of action can be questioned and supported by expert testimony for examining negligence.

One defense that falsely seems to comfort managers and owners is the "act of God." This defense used with hazard trees is challengeable and dependent upon two tests. To use the act-of-God concept in denying liability, a tree must be a native tree planted by nature and a tree must never have been significantly influenced by humans. Few trees in community and yard settings meet these two tests. Act-of-God has not proven to be an effective defense for negligence determinations.

Court Recommendations

As a manager, the court will ask you two basic questions after a catastrophic tree structural failure: 1) "Were the managers negligent or was the tree a nuisance?' and, 2) "Would the hazard have been recognized upon inspection?" As a manager you should be prepared to answer, and support your answer, for any actions or inactions you may have taken.

What do the courts recommend managers do to minimize liability risks? Three action items arise continually: A) perform a timely systematic inspection and keep it current; B) develop written documentation of risk management concerns; and, C) use risk assessment inspection results in current and future management. In many circumstances, a lack of a systematic inspection could be considered negligence.

Systematic Inspection

Systematic inspection demands observational discipline. The inspector must carefully examine a tree and make cumulative decisions about tree defects and associated target attributes. This inspection process should ideally include a root collar excavation, an aerial examination, and soil probing. Usually, some form of ground-based observation is used for cost-effectiveness. Only tree professionals experienced in risk assessment should perform these evaluations. General tree inventory crews may not be technically or experientially qualified to examine trees and sites for hazards.

To fulfill the legal aspects of a systematic inspection for risk factors, a precise and accurate methodology must be used. A training system will be presented here that has been proven to assist the risk assessors and new students unfamiliar with trees risk assessments. The basic tenet of this training system are observations begin where the stress and strain on a tree are the greatest. The handout shows the trees risk examination zones identified by number. Inspections begin at the base in zone 1 and expand outward and upward in zone order.

An inspection should begin with a general overview of tree structural integrity to provide for the personal safety of the inspector and the people and property in the immediate area at the time of inspection. From a distance and as the inspector approaches the tree and site, any immediately hazardous conditions should be noted. The assessment should not continue until these conditions have been corrected. The next step in the risk assessment process is to survey the tree from at least three opposing sides, close enough to the tree to notice subtle structural reactions by the tree over the years. At each of these observation sites, examine the tree looking for simple or compound structural faults.

On each side of the tree begin the assessment where stress and strain is the greatest and structural faults could have the greatest impact on tree integrity and target safety. One way of thinking about this assessment process is to start at the ground and build a good tree. Go up and out from the tree base until you have accumulated enough structural faults to put the tree at risk of failure. Identifying major structural faults that could lead to catastrophic failure is the point of this assessment. Finding simple major faults, or compound faults where simple structural faults have coalesced into a combination of problems, is the goal of this assessment system. Of course the extent and seriousness of a structural fault remains the professional decision of the assessor.

Tree Risk Training Guide

For training people to use this assessment system, a removal threshold must be set after which the risk of catastrophic failure becomes too great. This threshold is dependent upon management regime, site history'and species. For general purposes, the value of three major simple faults or one compound major fault that could lead to catastrophic loss are used. Assessors count up in zone order until the threshold is reached and then cease further risk assessment and move onto the next tree.

The zones for observation correspond to critical junctures or structural components in the tree. Zone 1 is the stems and root base four feet up the stem and four feet out from the stem. Zone 2 is the main stem from four feet above the ground up to where the main living branches begin. Zone 3 is the primary root support region extending out to 1/2 the drip line. Zone 4 is the primary branches out to l/3 their length. Zone 5 is the remainder of the structural roots. Zone 6 is the remainder of the crown.

Zone 1 comprises the bottom four feet of the stem and the roots holding the tree erect under compression out to the edge of the ZRT (zone of rapid taper) which is approximately feet. In this zone there should never be a compromise. If in doubt, take it out! If the base has multiple structural faults, it does not matter that the rest of the tree is perfect.

Zones 2 - 4 are areas of the tree where structural faults can be correctable with large inputs of time, money, labor, materials and technical maintenance. Any corrections inserted to aid in the structural maintenance of the tree may call attention to a preexisting structural condition. Correction activities may decrease failure risks but increase the chances of successfully determining negligence.

Zone 5 and 6 in the tree are areas where structural faults are not significant problems because they do not involve catastrophic tree loss and massive weights. Faults identified in this area are usually easily corrected. This does not mean that these zones should be ignored. A small branch falling from a long way can still provide life-threatening risks.

Level of Risk Acceptance

Once you have identified three major simple faults which could lead to catastrophic loss, accumulated in zone order for the tree, remove the tree. This is a risk assessment decision. There could be historic, social significance, biological and/or aesthetic reasons for accepting more risk, but that is a management decision that must be woven into risk assessment. Under some management regimes more risk can be accepted than others.

There are many hazard tree and tree risk assessment methods. Presented here is a simple training method to get people started and to insure systematic inspections. Many companies and public entities may have proprietary means of assessing risk. You need to look around at the different means of quantifying risk. One system is found in "A photographic guide to the evaluation of hazard trees in urban areas." (2nd edition) Matheny and Clark, authors. International Society of Arboriculture. Order by calling 91 O-789-4747.

Philosophic Assessment

There are many ways of trying to assess structural failure in trees and determine risk levels. The most basic revolves around a simple physic equation. A scientifically based assessment system could be built around $F = m * v^2$; where "F" is the total force of the impact, "m" is the mass of the object, and v is the velocity upon impact of the object as accelerated by gravity. In other words, "force equals mass times acceleration." The bigger the object and the farther it falls, the greater the force of the impact.

Using this equation, a risk manager would determine that the bigger the mass and the farther above the ground (greater potential energy), the greater the liability risk. The problem with this pure scientific determination is that force of impact (F) is not equal to specific damage awards, precise extent of medical injuries, or total liability costs and settlements. A free-falling, unencumbered limb is not normally expected because of other branches and other lines or objects in the way. A small twig with perfect location of impact and high enough velocity can initiate severe damage and death as well as a massive branch which crushes.

Liability case law paints with a wide brush. You cannot fine-tune tree hazards into a formula unless you account for settlement values and associated costs. Risk assessment remains a professional, subjective judgement based upon the experience of the assessor and how well the manager / owner has communicated real management objectives and willingness to accept risk. Risk assessment should not be considered a black and white, scientifically determined decision-making process.

Documenting Risk and Hazards

Managers need to help owners and resources users appreciate and understand the risks involved with trees. When writing a report or letter describing tree liability risks, you should be cautious of several things. The first is to carefully document how the assessment was performed by describing techniques, observations and judgments. For example, were there a ground and an aerial inspection, a ground inspection only, or was a root crown excavation completed? Do not use emotional, subjective, or aesthetic opinions and descriptions of the tree in documentation. For example, a tree may be described as having a "nice, full crown," but this tells nothing about the structural component risk assessment you are completing.

In documentation of tree risk assessment and in professional discussions, you must be able to discuss openly and fully your reasoning behind any risk assessment values. Always use a standard form to insure coverage of the important aspects of the assessment. Finally, it is crucial that you determine the actual owner of the tree and site. Trees on border lines or trees treated as borders need additional review with both owners. Get the facts, not someone's imaginings when assessing a tree. Do not take lay-people's word for trees occurrences and conditions -- see for yourself!

Non-Removal Hazards

So far we have discussed events leading to complete tree removal for reducing risk. There are many reasons for a tree to be considered as carrying significant risk but these may not be enough for removal. These problems occur commonly in managed landscapes and are termed "non-removal hazards." Some of these non-removal hazards include: buckling of pavement by roots (do not sacrifice a tree for $25.00 worth of cement); damage to building foundations, cisterns, and septic systems (use root barriers, release pressure, fix engineering problems not biological); presence of surface roots; presence of small dead wood pieces and litter (fruits, flowers, twigs, leaves); trees are living centers that house vertebrates and insects that present injury, disease, and nuisance risks to humans; entrapment in cavities, between branches, and in soil opening for animals and humans; face

level branches (dependent upon means of conveyance -- bike, skates, walking); serve to block views and interfere physically with safe traffic movement; line of sight obstructions for safety and security concerns; and, risks for property damage (fences, walls, roofs, etc.). Clearly this is not a comprehensive list but does provide suggestions for building awareness among employees, managers, owners, and users of the community forest.

Speciality Risk Areas

There are four additional speciality subjects that can generate tremendous risk exposures. These subjects will not be reviewed here as they are large areas of management in their own right. These risk assessment specialty areas are: storm damage management including lightning protection; cavity strength and treatments (Coder. 1989. "Should you or shouldn't you fill tree hollows?' Grounds Maintenance Magazine Vo1.24(#9)); development and construction activities including utility installation; and, maintenance and cultural activities on a site including pesticide and fertilizer concerns. Of these specialty areas, storm damage assessments are probably the most universally important while the most poorly completed.

Trees can be major aesthetic, social, and financial losses in storms. Trees can also be liability risks to primary access corridors, emergency personnel, and utility operations in storms. It is important to work with civil defense authorities to minimize storm damage potential, especially along prioritized access corridors. Trees can be low risk as assessed under normal conditions but become hazardous along primary access routes in storms. The management objective for a site and a tree determines liability risk acceptance. Minimizing storm damage and storm liability risks will not be covered here. The following citations may help: Coder. 1993, Storm damaged trees. Grounds Maintenance Magazine. Vo1.27(#2). and Coder. 199 1. Storm Damaged Trees: Prevention and Treatments. The University of Georgia Cooperative Extension Service Circular #806. Ppl5.

Conclusions

Managers can become confused and fearful of risk management inventories and mitigation processes. Increasing exposure to liability risks is a fact of life. Let us be aware and positive about this management opportunity. Risk assessment is an integral part of a good community forest management program. A community forest resources management program includes: A) training and pruning; B) tree vitality maintenance (water, fertilizer, and preventing damage); C) planting and planting space development; and, D) early problem identification (including liability risks).

The community forest manager needs to continue to follow total quality management processes for the best quality of life for the trees and the people.